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Solving Museum Insect Problems: Chemical Control

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Solving Museum Insect Problems: Chemical Control

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Abstract

Insect infestations can severely damage museum collections and buildings. This Technical Bulletin is intended as a guide to help museum staff understand commercial pest control operations. It describes chemical methods of controlling insects, and includes information on regulations, modes of action, and application methods necessary for the safe use of insecticides. Insecticide safety and poisoning are also discussed, and the properties and side-effects of specific insecticides are outlined. Pest-by-pest recommendations guide the reader in deciding upon the appropriate chemical method of control.

Cover

The cover photograph shows one method of chemical control of pests. Generally, it is best to engage professionals who are equipped to carry out this procedure in museums. Chemical control is often employed after all other methods have been tried and have failed. Do not allow the pesticides to come into contact with artifacts.

Photo by Carl Bigras, CCI.

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1. Introduction

Museum collections include a wide range of organic materials, such as paper, wood, cotton, linen, hemp, hides, leather, furs, horn, baleen, wool, and feathers. Such materials are prone to biodeterioration through attack by insects, fungi, and rodents. Damage can vary from a few holes in an artifact to its complete destruction.

The most effective means of control is prevention through regular inspection, good housekeeping, and regular maintenance of the building, as described in Technical Bulletins 12 and 13. If an infestation does occur that makes nonchemical or chemical control methods necessary, preventive methods should be reassessed to avoid a recurrence.

The nature and extent of the damage depend not only on the insect and material, but also on how promptly the infestation is discovered and controlled.

Regardless of the magnitude of the infestation, the initial step following its discovery is to identify the insect. Consult a local pest control agency, university or government entomologist or contact CCI for help in identifying insect pests (see Appendix 1).

Determine the extent of the infestation; it is important that the individuals carrying out the examination know what they are looking for. The investigation must find the source of the insects in order to prevent a recurrence.

Once the insect has been identified, the method of control must be selected. Nonchemical methods are the first choice because they are safer and easier to administer than are chemical methods. Isolation of artifacts, mechanical cleaning, and low temperature are among the nonchemical options open to museums.

Chemical methods of control may be required if other techniques prove ineffective. Care must be exercised in choosing the appropriate insecticide, taking into consideration the safety of artifacts and the well-being of staff. By acquiring a rudimentary knowledge of insecticides, museum staff are better able to work effectively with pest control operators. To help in this regard, this Bulletin provides information on government regulations, modes of action and reactivity of insecticides, toxicity and Threshold Limit Values, methods of application, early symptoms of poisoning, and pest-by-pest recommendations.

Insecticides are chemical products used to prevent, destroy, or repel insects. These products vary in mode of action, effectiveness against specific insects, and method of application. Insecticides are dangerous. For this reason, they should only be used in a limited, localized manner by museum personnel. Large-scale or specialized applications require licensed pest control operators who are trained and who have the necessary protective and application equipment.

Within museums, the proper choice of insecticide depends not only on its effectiveness against the insect discovered, but on the safety of the product for artifacts and staff. Commercial products should be used only if their active ingredients and solvent bases are known and have been proven to be safe. Many products have the same active ingredient but have different trade names. Those available from grocery, drug, and hardware stores are not necessarily without dangers. It is important to follow the manufacturer's instructions exactly and to use the product only for the insects listed on the label.

Insecticides, protective clothing, and equipment are easy enough to acquire, but not so easy to use correctly and safely. Insecticides present the further problems of safe storage and disposal. For these reasons, contracting the services of a licensed pest control operator is often the safest solution.

Even when assigning large-scale application to pest control operators, the museum must still assume responsibility for the effects of the operation. It is important to choose an operator with knowledge of the special needs of museums and of the sensitive nature of artifacts. The proposed chemicals and procedures should be discussed in detail with the operator, and conformity to regulations should be ensured. Museum staff should be briefed on the procedure and on potential health hazards, since sensitivity to chemicals varies from individual to individual. Museums can consult other experts in the field before the treatment is undertaken (see Appendix 1).

Museums are advised to consult other publications, some of which are listed in the Bibliography, for an in-depth understanding of insecticides.

2. Regulations Governing Insecticides

Because insecticides are potentially hazardous, every insecticide sold in Canada must be registered with Agriculture Canada by the manufacturer, and must be assigned a Pest Control Products Act Registration Number (Registration No. P.C.P. Act) that should appear on its label. Products without this registration number must not be used. Because provinces may prohibit the use of some products registered federally, it is necessary to consult provincial authorities (departments of agriculture, the environment, or labour) before using them. For the same reason, municipal or local regulations should also be consulted. Products classified for general use can be applied by anyone, in accordance with the instructions on the label. Those classified for restricted use must be applied by a certified operator or under the supervision of a certified operator.

Information on insecticide labels must be strictly followed with respect to application, dosage, and target pests.

3. Modes of Action

Insecticides are often classified by mode of action. Depending on the method of application, some insecticides may have more than one mode of action.

Stomach Poisons
These products must be consumed and absorbed by the alimentary canal. Stomach poisons (e.g., ant baits, arsenic), which are used for insects with chewing mouth parts, function by interfering with normal operation of the nervous system.

Contact Insecticides
These products (e.g., diazinon, pyrethrum, chlordane) must come into contact with the insect and must penetrate the cuticle and body wall. Contact insecticides function by interfering with normal operation of the nervous system.

Residual Insecticides
These insecticides are effective when they contact the insect during or after application. The active period, or persistence, varies from product to product. Persistence depends on temperature, relative humidity, formulation, location, and nature of the treated material. Residual insecticides include, in descending order of persistence, inorganic, chlorinated, carbamate, organophosphate, and botanical compounds. Because these insecticides function over a longer period than do other types, health risks are extended. Residual insecticides should therefore be avoided unless they are the only effective method of control (e.g., for subterranean termites).

Desiccant Insecticides
This type of insecticide is an inert silicaceous powder that absorbs part of the outer protective wax coating of an insect, causing dehydration and eventual death. Desiccant insecticides are very useful for building insect control into hard-to-access locations where they will not be disturbed by cleaning activity, water, or air movement. Indicate the presence of these insecticides when they are used under or within museum displays so that staff will know of their presence and not treat them as dust to be cleaned up.

Insect Growth Regulators
Juvenile hormone analogs are natural or synthetic compounds that restrain insect maturation. Three common juvenile hormone analogs are methoprene, hydroprene, and fenoxycarb. These slowly volatile compounds are useful for breaking the reproductive cycle of a population, such as cockroaches. The juvenile hormone analogs do extend the larval or immature stage that is often the most damaging in museum collections. Their use has more traditionally been against fleas and mosquitoes to curtail damage by the adult insect. The registration of methoprene has been extended to cover stored product pests in agricultural commodities.

Fumigants
These insecticides, in vapour or gas form, enter the insect through the body wall or the spiracles (respiratory openings). Fumigants are most often used in sealed chambers. Some fumigants are mixed with other gasses to reduce flammability. Other fumigants, in solid or liquid form, produce vapour when volatilized. Fumigants are effective against insects that are inaccessible to regular insecticides, but are effective against all stages of insect development (egg to adult) only with adequate concentration and exposure. Fumigation will not prevent reinfestation where preventive methods are not practiced or where conditions are conducive to insect activity.

4. Insecticide Formulations

Most insecticides are available in a number of formulations, usually mixtures of the technical-grade insecticide (full strength) with various solvents or inert substances.

Oil Concentrates
Oil concentrates are concentrated solutions of insecticide in a solvent (e.g., deodorized kerosene, various light oils). The concentrate can be further diluted as indicated on the label. These solutions flow readily into cracks and crevices, and penetrate porous materials. Since the solvent can affect some plastics (e.g., insulation on electrical wiring), care must be taken to avoid these materials during application.

Emulsifiable Concentrates
In emulsifiable concentrates, an emulsifying agent is added to an oil concentrate insecticide to allow it to be mixed with water. Emulsions tend to penetrate porous materials to a lesser extent than do oil concentrates.

Wettable Powders
These insecticides are mixed with an inert powder (e.g., clay) and a wetting agent. Water is then added to form a suspension that can be easily sprayed on infested objects. Only the water penetrates porous materials, leaving a visible deposit on the surface.

Dusts
A pure insecticide powder or a mixture of the insecticide and an inert carrier powder such as chalk or clay can be applied directly to wall voids, cracks, and crevices, leaving an active residue. Dusts should be used only where they are unlikely to come into contact with people. Desiccant powders are often combined with insecticides, creating a double-acting formulation with prolonged action.

Baited Insecticides
These are mixtures of an insecticide and a food substance that attract insects.

Microencapsulated Insecticides
Some insecticides are sealed in microscopic porous plastic beads through which they slowly diffuse or from which

they are released upon rupture of the bead. This process extends the activity of an insecticide over a longer period, and reduces its toxicity to people and to nontarget animals.

Resin or Pest Strips
Pest strips consist of a polymer resin (usually polyvinyl chloride) impregnated with an insecticide (normally dichlorvos). The insecticide slowly volatilizes from the plastic.

5. Application Methods and Possible Problems

It is important for museum personnel to be acquainted with the application methods for different types of insecticides and with the problems that might arise from the application, even if it is to be carried out by a pest control operator.

Someone on staff should be aware of where the pest control operator is working, the estimated completion time for the application, and the insecticide that is being applied. This knowledge is important for responding to a medical emergency caused by pesticide exposure (see Section 8).

Upon completion of the application, the operator should report to the contact person. If the operator has not reported, the contact person should investigate to determine if the job is taking longer than planned or if the applicator is in trouble. Particularly in the case of fogging or fumigation, the contact person must not enter the treated area without the proper safety equipment.

Spraying
Spraying is used to apply insecticides in water, oil, emulsion, or wettable powder formulations. Sprayers are pressurized devices designed to apply the insecticides. Air pressure can be supplied by means of hand-operated or power-driven pumps. Sprayers vary in capacity, tank construction, and type of nozzle. Depending on the nozzle, a sprayer can deliver anything from a solid stream to a fine mist.

The size of sprayer and the type of nozzle should be appropriate to the job. The insecticide label will indicate whether the sprayer should be made of plastic or metal. Use and maintain the sprayer according to the manufacturer's directions. Wear protective equipment — a full-face respirator with canister or cartridges designed for the specific insecticide, gloves made of a material impervious to the specific insecticide formulation, and coveralls or other protective garments — during all stages of the operation. If the carrier solvents are flammable, keep an all-purpose fire extinguisher on hand.

Before applying a spray, it is essential to be aware not only of the effects of the insecticide on artifacts, but also of the components of the formulation. Insecticides are mixed with different solvents or carriers, referred to as supplementary substances. Care must be taken in applying these formulations to materials that might be damaged by them.

Decide on a route for each area that is to be sprayed. A floor plan of the museum is useful for this purpose. Evacuate the area to be treated before beginning the spraying. Notify staff and post warning signs at all entrances. If the solvents are flammable, turn off all electrical apparatus or devices with an open flame. Remove personal effects, live plants, and animals from the area. Do not permit anyone to re-enter the area until sufficient time has elapsed to ensure that the spray is completely settled and dry.

The following three problems may arise from spraying:

(a) Water-based insecticides may stain or water-mark some surfaces. Pigments, inks, or other sensitive materials may be soluble in water, resulting in discolouration. Water may damage organic materials (e.g., leather may become hard and brittle).

(b) The organic solvent in some insecticides (e.g., oil, kerosene, petroleum distillates) may damage a wide range of materials: fabric dyes, wallpaper dyes, synthetic fibres (e.g., rayon), silk, paints and finishes, plastics, linoleum, rubber, asphalt, floor tiles, porous materials (e.g., concrete, wood), and parquet floors where adhesives may be softened or dissolved.

(c) Unless areas sprayed with an emulsion are allowed to dry, the emulsifier, acting like soap, will remove dirt from shoes, etc., forming a stain on carpets or on other surfaces. Emulsifiers can lift wax from floors or furniture, and may harm coloured fabrics that are not colourfast.

In order to be certain of the effects of an insecticide, spot-test it on materials prior to using it generally. To carry out a spot test, apply a small amount of the formulation to a small area that will not be observed or, if possible, to scraps of the same type of material. Allow the insecticide to dry before making observations. Spot tests will help in noting immediate, but not subtle or long-term, changes.

In some cases, it may be necessary to move sensitive items away from the area of treatment or to enclose them carefully and completely with a polyethylene sheet.

Aerosol Bombs
Aerosol bombs are insecticide solutions, usually oil-based formulations, under pressure in self-dispensing containers. The insecticide can be dispensed in a solid stream or a fine mist, depending on the type of nozzle used. The size of the container varies. Generally, dispensers have small push-button valves that close when pressure on the button is released.

Consider aerosol bomb applications only for small, localized problems. A major problem should not be

resolved by using a greater number of aerosol bombs.

Aerosol bombs must be used according to the label instructions and only for the specified insects. Avoid user contact with the insecticide. Point the nozzle away from the user. Evacuate the area before application, notify staff, and post warning signs. Do not use near open flames or sources of heat. Dispose of aerosol bombs as soon as they are empty; empty cans under pressure are dangerous if punctured or incinerated.

Fogging

Fogging is used to control a wide range of insect pests that attack organic materials other than wood, because it permits rapid treatment of a large enclosed space with relatively small quantities of insecticide.

Fogging produces a cloud of very fine droplets of insecticide in a volatile oil by means of a thermal aerosol generator or a fogger designed for indoor use. The oil-based insecticide formulation is introduced into a heated chamber, resulting in immediate vaporization of the oil. The droplets produced fill a room or an improvised plastic tent with a dense fog. The suspended insecticide is deposited on the exposed surfaces, and the oil droplets slowly evaporate.

Because of the problems noted in Section 4 for oil-based insecticides, considerable care is required to avoid dampening and thereby damaging materials, especially artifacts.

The individual carrying out the fogging must be thoroughly familiar with the operating instructions supplied by the manufacturer of the fogger.

Appropriate safety devices are essential: a well-fitting fullface respirator with a canister or cartridges approved for filtering the insecticide, gloves made of a material impervious to the insecticide (e.g., neoprene), coveralls or other protective garments to avoid skin exposure, and an all-purpose fire extinguisher.

The formulation used for indoor fogging is usually a pyrethrum insecticide. For museum use, the insecticide formulation should not contain a residual component (see Section 3).

If the insecticide injected into a closed space exceeds one litre per 350 cubic metres, an explosive atmosphere may be created.

Before beginning the fogging, warn neighbours, evacuate the room, and seal all windows, doors, and other openings to the outside (excluding the exit door). Turn off the ventilation system, all electrical apparatus, and any devices with an open flame. Remove personal effects, foodstuffs, live plants, animals, and uninfested artifacts.

Plan a route for each area, especially if it is a large room in which the fogger will have to be moved to several locations. Start in the farthest corner and move in the shortest path, permitting the fog to be directed above, under, and behind objects. Ensure that the fog reaches the ceiling and upper corners of the room. Finish at the exit, where the door should be unlocked and a warning sign posted before the fogging to be certain of a safe egress from the room.

Lock the treated area after fogging to prevent accidental entry, and post warning signs at all entrances. Do not permit re-entry for at least 12 hours or for the time specified on the insecticide label. Open screened windows and doors to flush the area with fresh air before re-entry. Halfway through ventilating the area, turn the ventilation system on to ensure that the insecticide is flushed out of the ducts.

The applied fog will not move into cracks and crevices, which are often principal harbourages for insects, unless air movement carries it in.

Only adult, pupal, and larval stages directly contacted by the insecticide will be killed; eggs will not be killed. Many insect pests (e.g., carpet beetles, clothes moths) may be well sheltered from the fog because of their tendency to hide in small crevices or to burrow within artifacts. To achieve higher mortality, arrange the infested material so as to permit the most complete exposure to the insecticide. A second fogging 20 to 30 days after the first may be necessary. If so, maintain the infested area at 25°C from before the first fogging begins until after the second is complete to ensure that newly hatched insects are vulnerable to the insecticide. Even with repeated foggings, some of the insects may not be exposed to the insecticide. Clean throughly to remove insect carcasses. Do not rely on fogging alone to bring about complete control of an infestation. Prevention and some means of nonchemical control will also be necessary.

Dusting

Dust insecticides are not effective in damp areas, and their effectiveness is reduced in areas that are already dusty. They may have a tendency to absorb oils from natural fibres, possibly leaving fibres brittle and subject to damage; dust insecticides should therefore not be applied directly to an object. Dusts are applied with the use of dusters — devices varying in size and mode of operation from the squeeze bulb or bellows-type to the plunger (a small air pump with a chamber to hold the dust), all of which suit most general requirements. If a large area is to be treated, then hand-crank-operated, electrically driven, or compressed-air dusters should be considered.

Before using a duster, read the manufacturer's instructions carefully, and ensure that the proposed dust is registered for the use and insect in question.

Wear protective equipment (approved dust mask, goggles, gloves, and protective clothing) to prevent contact with the

dust during application. Prior to carrying out dusting, decide on a route that ends at the exit door.

Post warning signs, and indicate to staff where the dust has been used. Do not permit re-entry until the dust has settled. Areas where humans, especially children, will contact treated surfaces should not be dusted.

Fumigation
Fumigation disperses a toxic chemical so that it reaches the organism in a gaseous state. Fumigation can be carried out at atmospheric pressure or in vacuum chambers. Any structure that can be made sufficiently air tight for the length of time required can be fumigated at atmospheric pressure. Vacuum fumigation requires a specially constructed chamber capable of withstanding external pressure of up to one atmosphere. A vacuum system also requires a pump for introducing and exhausting the fumigant. Both methods require a separate ventilation system for the area around the chamber. A locked barrier around the chamber will prevent tampering or accidental interference during fumigation. The chamber should be in a room separate from collections or display, and access should be restricted to those involved in its use. Post warning signs, and do not shorten the recommended aeration period for any reason. Vacuum fumigation increases penetration by the fumigant, ensuring greater mortality of insect eggs. For this reason, vacuum fumigation was typically utilized in the past by museums. Fumigation will kill only the pests present at the time of fumigation, and will not prevent reinfestation.

Ensure that the fumigant is compatible with the material on which it is to be used. Avoid wetting artifacts with the fumigant; several cases of severe damage to artifacts during pest control operations are due to this type of accident.

Fumigation is considerably more expensive than other types of insecticide application. Procedures for using the fumigation apparatus will be supplied by the manufacturer, and should be fully understood before beginning. Since extensive coverage of the principles, applications, and protective devices for fumigation is not within the scope of this Bulletin, the reader is advised to consult the references listed in the Bibliography. Appendix 2 lists fumigation chamber manufacturers.

6. Safety Equipment and Monitors

When choosing a monitoring system, ensure that it is sensitive to low levels of the fumigant (at least to the level of the TLV), and that it can be easily operated and maintained. Ascertain from the technical literature, the manufacturer, or the supplier what types of volatile substances interfere with the monitoring of the fumigant, and whether these are likely to be encountered either during the application or in the local environment.

Monitoring equipment will be one of the following types: detector tube, electronic sensor, or monitoring badge.

Detector tube systems mechanically force gas through a tube containing a chemical reagent that reacts with the fumigant to produce a coloured stain. Detector tube systems require several minutes to obtain a reading of fumigant concentration. The length of the stain indicates the concentration. Detector tubes are disposable and can be used for only one reading.

Electronic systems provide an instantaneous reading of gas concentration. They are usually more sensitive, and more expensive, than detector tube systems. The lower levels of residue and exposure for many fumigants now require the use of gas chromatographs, a type of electronic monitoring system, as detectors.

Monitoring badges, or passive dosimeters, do not operate through pumps or batteries. The badge is clipped onto a collar or lapel. For a period of up to eight hours, the gas enters the monitor by diffusion and is absorbed by the medium inside the monitor. The sampling is continuous and gives a time-weighted average exposure during the eight-hour working shift. Some types of badges are then sent to a laboratory for analysis, while others can be read on site with the appropriate equipment.

Monitors and other safety equipment, such as gloves, respirators, goggles, and protective garments, can be obtained from major safety suppliers. Before purchasing monitors or safety equipment, check with the manufacturer of the fumigant and with provincial and federal regulatory agencies to obtain their recommendations for the appropriate types.

Maintain all apparatus, including safety and monitoring equipment, according to the manufacturer's instructions. As with fumigation chambers and pumping equipment, a yearly inspection by the manufacturer's technical representative is recommended. Some regulatory agencies may recommend even more frequent inspections. Use gas detectors during every fumigation to check for leaks. During chamber fumigation, carry out monitoring around the chamber door, the pumping equipment, and the gas cylinder.

Ventilate the areas around the chamber to the outdoors and not to the system serving the rest of the building. Obtain information about the required capability of the ventilation system from provincial or federal regulatory agencies.

For all applications or fumigants or other insecticides, keep a record indicating

(a) the name of the operator;

(b) the amount of fumigant used;

(c) the date, time, and duration of the fumigation;

(d) the nature of the artifacts exposed to fumigant (e.g., colour, size, type of materials);

(e) the reason for the fumigation (e.g., insects, fungi [note the species when known]);

(f) the duration of the aeration and the names of personnel who handled the fumigated material during aeration;

(g) all tests carried out to measure fumigant levels, and the readings obtained;

(h) alteration in the artifacts believed to be due to the fumigation; and

(i) health problems believed to be related to the use of the fumigant.

Prepare a checklist defining each step in the fumigation procedure, from placing the objects in the chamber to final monitoring of the aerated material. Initial and date the completed list, and file it for future reference. Long-term records of exposure and medical examinations of personnel using fumigants are often required.

7. Other Chemical Methods

Repellents
Repellents such as naphthalene and paradichlorobenzene deter insects from feeding on artifacts. See Section 10 for precautions and relative advantages regarding these substances.

Cedar chests give some protection for materials prone to attack by insects, provided that the lids close tightly. The odour from the cedar, produced by volatile compounds in the wood, reportedly repels insects. Similarly, cedar chips have been used in lieu of chemicals to repel moths. The effectiveness of cedar chests or chips lessens as the volatile chemicals dissipate.

Cedar chests have disadvantages and limitations. If an infested artifact is placed inside a cedar chest, it is unlikely that the infestation will be eradicated or controlled. The aromatic, volatile compounds given off by the cedar can also leave a film on surfaces.

Commercial Dry Cleaning
Commercial dry-cleaning processes use solvents to remove grease, oil, fat, and dirt from textile materials. Perchloroethylene, the principal dry-cleaning solvent, is sometimes supplemented with detergents and water to ensure complete cleaning. Dry cleaning not only removes food sources that an insect can feed on, but kills eggs, larvae, pupae, and adult insects. Fungi that have become active on wet garments will also be killed. Dry-cleaned wool and other fabrics are less susceptible, though not immune, to attack by clothes moths.

Four points should be considered before dry cleaning is undertaken:

(a) Detergents used to supplement the dry cleaning may harm some materials.

(b) The material must be strong enough to withstand the tumbling action of the process.

(c) All components of garments, uniforms, etc., should be known, and the effect of the process on each understood. In some cases, it may be possible to remove materials that could be affected. The advice of a textile conservator should be sought in such instances. The fabric must be able to withstand the temperature in the drying cycle. While wool does not present a problem, some synthetics may.

Plastic or celluloid beads and buttons, laminates, pigment prints, acrylics, leathers, suedes, silks, and trimmings may be either impossible to clean with the dry-cleaning solvent or may require extreme care to avoid solvent and/or temperature damage.

(d) Infested material on which dry cleaning is to be carried out should initially be thoroughly vacuumed.

8. Insecticide Safety and Poisoning

If staff develop symptoms while using insecticides, after using them, after coming in contact with treated materials, or after working in an area that has been treated, immediately remove the individual from the area and seek medical help. Provide the doctor with the specific formulation of the insecticide, not just the trade name.

The following tend to be the most common symptoms of mild poisoning (often referred to as acute poisoning from single-dose or short-term exposure), or the early indications of more serious poisoning: headache, fatigue, dizziness, nausea, vomiting, general weakness, blurred vision, abnormal sweating and salivation, stomach cramps or diarrhoea, tightness in the chest, generalized aching, and muscle twitching (see Section 10 for symptoms of specific insecticides).

Four general first aid steps can be employed when dealing with insecticides:

(a) If the insecticide contacts the skin, wash the area with soap and water immediately.

(b) If the insecticide contacts the eyes, flush them with water immediately. Consider a follow-up examination by a doctor, particularly if eye problems occur.

(c) Remove any individual who has inhaled large amounts of an insecticide to fresh air, and perform artificial respiration if necessary. Then get medical attention for the victim.

(d) If an insecticide is swallowed, get immediate medical attention. If the insecticide solvent is a petroleum distillate, such as diesel oil or kerosene, or if the individual is unconscious, do not induce vomiting; vomiting may cause the chemical to be aspirated into the victim's lungs.

Post the emergency numbers for ambulance services, fire departments, police stations, and Poison Control Centres.

9. Pest-By-Pest Recommendations: Chemical Treatment

Once an infested object has been discovered and the insect has been identified, the museum must take immediate action to eradicate the insect and to prevent widespread infestation. Only when preventive and nonchemical measures have failed should the chemical methods listed on the following pages be undertaken.

Before proceeding with chemical treatment, it is essential that the reader refer to Section 10 of this Bulletin, "Properties and Side Effects of Specific Insecticides," and to Sections 5 and 6, "Application Methods and Possible Problems," and "Safety Equipment and Monitors." Always continue to use preventive and nonchemical methods to ensure the effectiveness of chemical treatments.

This section outlines the various approaches that can be considered when using insecticides. The user is urged first and foremost to follow instructions on the insecticide label. As new formulations and new insecticides are manufactured, products not referred to in this Bulletin may be encountered. Use the basic criteria presented in this Bulletin to determine whether the insecticide meets specific requirements. If further information is required, contact the provincial or federal regulatory agencies or CCI.

Booklice

Chemical methods are not usually required for booklice. Additional information can be obtained from CCI if an infestation does not respond to nonchemical methods.

Silverfish and Firebrats

If an infestation is severe, it may be necessary to employ insecticides to control the problem. However, insecticides alone should not be used to deal with silverfish or firebrats because they do not eliminate the causes of the problem: elevated temperature and high humidity. Insecticides should be used only as a complement to nonchemical methods.

Treat cracks and crevices, baseboards and spaces behind them, cupboards, shelving, storage cabinets, crawl spaces around pipes, wall voids, and other possible hiding places.

A wide range of residual liquid sprays and residual dusts have been used to deal with silverfish and firebrats. Sprays based on diazinon, propoxur, dichlorvos, chlorpyrifos, pyrethrins, and microencapsulated pyrethrins can be used; of these insecticides, the safest are the microencapsulated pyrethrins. Dusts formulated with diazinon, silica aerogel, or boric acid powder can be used; the latter two are preferred, silica aerogel being the safest. A formulation of pyrethrins and silica aerogel is also effective.

Do not use these insecticides directly on artifacts,

Cockroaches

If nonchemical methods have not controlled the infestation or if the infestation is heavy and widespread, chemical methods will be necessary.

Dusts and residual sprays can be used to treat harbourages such as cracks and crevices; cupboards; spaces behind drawers, under sinks, around pipes and baseboards, and under radiators or appliances; and any other dark, warm, damp places. Dust is the best method for treating cracks, crevices, and hollow areas such as wall voids less accessible to sprays. Use a light application of a dust since heavy applications tend to repel insects. Dust formulations combining pyrethrin with diazinon, bendiocarb, carbaryl, or silica aerogel are effective. The silica aerogel-pyrethrin combination is the safest. Other relatively safe types of insecticides that can be effectively employed in the same manner as dusts are powders containing boric acid formulations. Do not use these insecticides directly on artifacts.

A fine, pin-stream nozzle is appropriate for crack and crevice treatment. For broader treatment, fan-type or cone-type nozzles are recommended. Surfaces should just be dampened, not wetted to the point of runoff. Formulation insecticides, such as diazinon, propoxur, chlorpyrifos, malathion, bendiocarb, and microencapsulated pyrethrins, are effective; of these, microencapsulated pyrethrins appear to be the safest. If sprays and dusts are used in combination, apply the sprays first and allow them to dry before applying dusts.

In major infestations, contact or space sprays (e.g., dichlorvos, pyrethrins with added synergists, synthetic pyrethrins) may be used to flush out cockroaches and hasten control. However, this approach may help to drive the cockroaches into untreated adjacent areas.

Baits containing many of the aforementioned insecticides can be used to supplement dusts and sprays. Their use should be avoided in areas where they might be touched, particularly by children.

The development of a resistance to chlorinated insecticides in some species of cockroach has reduced the effectiveness of these insecticides.

Common Furniture Beetles, Death Watch Beetles, True Powder Post Beetles, House Longhorn Beetles, Drywood Termites, and False Powder Post Beetles
Fumigation in a vacuum chamber can be an effective method of eradicating wood-boring insects because it penetrates the entire object, thereby totally eliminating the insect. Methyl bromide has been used to treat wooden artifacts, but it is not advisable to use it on composite artifacts that contain fur, leather, horse hair, rubber, or woollen material. Ethylene oxide or sulphuryl fluoride fumigants can be used to treat wooden objects and composite artifacts. A thorough aeration is then required before the material can be handled, and this can be a lengthy process.

The aforementioned fumigants will kill all stages of the insect, but will not prevent reinfestation. Because of increased concern over the safety of fumigants, the use of methyl bromide and ethylene oxide is being reinvestigated by Agriculture Canada and by Health and Welfare Canada. Changes in registration and application procedures can be expected.

Atmospheric fumigation using methyl bromide can be very effective against wood-boring insects in wooden structures. A pest control operator can provide advice as to its appropriateness. A properly aerated fumigation does not protect the structure from reinfestation. If possible, artifacts should be removed from the building before fumigation to avoid needlessly exposing noninfested materials. In situations where items cannot be removed, discuss the need for protecting them with the pest control operator.

If structural timbers are infested, the strength of the infested wood should be assessed by an engineer to determine whether the timbers have become weak enough to warrant strengthening or replacement. This assessment should be carried out prior to applying any insecticide or fumigant.

Nonfumigant insecticides are an alternative to fumigants. For large areas, the insecticide is normally applied by spraying or by injecting the insecticide into the timber through drilled holes. The latter method can be useful in areas where timbers are joined. Flight holes in small objects can be injected with a residual insecticide using a syringe. A 10 cc plastic syringe with an 18-gauge needle is appropriate for this procedure. Cut a small circle of rubber approximately 1 cm in diameter, from an old inner tube or material of a comparable thickness, to act as a cover for the flight hole during injection. Cut or grind down the needle until it projects approximately 2 mm past the rubber. Inject insecticide into flight holes every inch or so to obtain thorough coverage. If no other method is available, this approach is reasonable for treating small objects. However, it becomes less effective and very time consuming for larger objects.

Wear disposable plastic gloves rated for use with the solvent and pesticide, and replace them if they become torn or punctured. Wear a lab coat or other protective clothing, and launder it before wearing it again. Protective goggles and a properly fitting respirator with cartridges suitable for the insecticide formulation should be used for added protection. Dispose of syringes, gloves, rags, and empty insecticide containers, keeping in mind that the solvents are flammable. Always follow the manufacturer's directions and precautions.

To ensure that the insecticide does not stain or discolour the object or its finish, perform a spot test on an inconspicuous area, and allow the insecticide to dry thoroughly before assessing the effect.

Insecticides are normally applied in a hydrocarbon solvent; if kerosene is the solvent, the deodorized product is preferable. Because solvents are flammable, a fire hazard will be present until the solvent has evaporated. The need for safety precautions and specialized equipment in the application makes it wise to employ a licensed pest control operator to carry out most insecticide treatments of infested wood.

Use of a short-term residual, such as diazinon, which resides for days to weeks depending on the formulation, would probably necessitate several applications of the insecticide to achieve control. Because it is a short-term residual, potential health problems are reduced. Avoid contact with the treated surface for several weeks.

Long-term residuals, which are present for years, are effective against wood borers. They kill larvae and emerging adults near the surface, and provide protection against reinfestation. Although the health hazard from the use of long-term residuals is considered to be low because of the relatively low concentrations required and because of their low vapour pressure, it is still necessary to avoid frequent contact with treated surfaces. Long-term residuals are not recommended for surfaces that might be touched by children.

Indoor use of wood preservatives containing chlorophenols, particularly pentachlorophenol, is illegal.

If a pest control operator suggests insecticides other than those recommended here, contact CCI to ascertain their suitability.

The best time to apply insecticides is in the spring, when the weather becomes consistently warm and insects are active in wood. If required, subsequent applications of short-term residuals can be carried out in summer or early autumn.

Be aware that these methods may not be 100% effective in controlling wood-boring insects because of the difficulties in thoroughly and adequately treating infested areas.

Subterranean Termites
Neither fumigation nor the normal methods of treating infested wood will control an infestation of subterranean termites because their nests are in the soil and not in the wood. Fortunately, these termites are not a widespread problem in Canada; at present, they are found only in southern Ontario and southern British Columbia.

Control of these pests involves treating the soil around and often under a building with a long-term residual insecticide in order to kill existing termites and prevent reinfestation. The aim of the treatment is to create a chemical barrier between the termites in the soil and tile wood in the building. A more detailed description of application methods is outside the scope of this Bulletin. Consult the Sources listed in Appendix 1.

Because of the methods of application and the very toxic nature of the required insecticides, fumigation must be carried out by licensed pest control operators, who must exercise extreme caution to avoid contaminating the building or water sources. Because the insecticides recommended for treating subterranean termites are changing, it is best to contact provincial and federal regulatory agencies for current information.

Larder Beetles, Hide Beetles, Common Carpet Beetles, Varied Carpet Beetles, Black Carpet Beetles, Common Clothes Moths, Casemaking Clothes Moths, Cigarette Beetles, and Drugstore Beetles
A thorough use of nonchemical methods should be effective in controlling infestations of these insects, particularly in artifacts. However, if nonchemical methods have failed or are not suitable for the specific problem, chemical methods must be considered.

Until recently, vacuum chamber fumigation of artifacts using an ethylene oxide fumigant would have been a standard procedure to remedy an infestation, However, increasingly stringent requirements, health and safety concerns, and potential deleterious effects on materials have caused museums to reconsider this method. Information on ethylene oxide is presented in Section 10 of this Bulletin. Sections 5 and 6 provide directions on fumigation methods and required safety equipment.

Paradichlorobenzene, naphthalene, and dichlorvos have all been used to control infestations in artifacts. However, as discussed in Section 10, use of these insecticides can cause problems.

Museums have used fogging with pyrethrum or pyrethrins to control heavy and/or widespread infestations. This procedure should be carried out by licensed pest control operators. A discussion of fogging is presented in Section 5, and information on pyrethrum may be found in Section 10 of this Bulletin.

Do not apply insecticides directly onto artifacts. Do not return artifacts to display or storage until these areas have been inspected and treated. Even when chemical methods are deemed necessary, good housekeeping methods should be carried out prior to applying an insecticide.

Areas where these insects hide should receive special treatment. Directions given in this Bulletin for silverfish are appropriate for these insects as well. Ensure that the insecticide is registered for the particular pest and application required. Before attempting a do-it-yourself approach, assess very carefully whether or not the application can be carried out efficiently and safely. If in doubt, contact a licensed pest control operator, ensuring first that you are well versed with materials and procedures.

Carpenter Ants
Applying insecticides is the only means of eradicating ant nests. If nests are not located, any control methods will be temporary at best. Borax ant baits that are carried back to the nest can be effective.

Force dust formulations registered for ants, such as carbaryl or a combination of silica aerogel and pyrethrins, into nests through holes drilled for that purpose. A silica aerogel and pyrethrin combination is safest and most effective, especially in dry areas. Also treat areas immediately around nests over which the ants may crawl. Sprays registered for ants, such as chlorpyrifos, propoxur, or diazinon, can also be used to treat nests and surrounding areas. Of these, a microencapsulated formulation of diazinon is the safest. Dusts are more suitable for cracks, crevices, and voids, while sprays are best suited to areas where dust might be unsightly. A combination of the two may be necessary.

If the nest is not discovered, the areas where ants are observed can be treated as an interim measure using the previously mentioned insecticides.

Bark Beetles and Abrosia Beetles
Since these beetles do not reinfest dry, seasoned wood, chemical control should not be required. However, if the potential emergence of adults from infested wood is not acceptable and nonchemical methods are considered unsuitable, fumigation or surface applications of an insecticide for other wood-boring beetles could be considered.

Wharf Borers
A spray with a contact insecticide, such as pyrethrin, registered for use on beetles is effective in controlling emerging wharf borers. If replacement of rotten, infested wood is not required or possible, it may be necessary to apply chemicals with fungicidal properties. Pentachlorophenol has often been recommended except for finished or painted surfaces, but is no longer available for indoor use. Zinc naphthenate is preferred as a substitute.

10. Properties and Side Effects of Specific Insecticides

A list of insecticides follows giving synonyms, classification, registration number, uses, and characteristics for each. When considering a new insecticide, request information in these same categories prior to use.

Explanation of Terms

The **Threshold Limit Value (TLV)** is the average airborne concentration of toxicant that can be tolerated on a repetitive basis without adverse effects, usually over five eight-hour days. The word "skin" following TLV refers to the contribution of skin contact to the total exposure.

The **Short-Term Exposure Limit (STEL)** is the maximum concentration to which workers can be exposed continuously for 15 minutes without suffering from irritation, chronic or reversible tissue change, or narcosis of sufficient degree to increase proneness to accident, impair self-rescue, or materially reduce work efficiency. No more than four exposures per day are permitted at the STEL specified, with at least 60 minutes of relief between exposures.

The **CAS Registry Number** refers to the registry system of the Chemical Abstracts Service.

The **Lethal Dose (LD_{50})** is the number of milligrams of the insecticide per kilogram (1000 grams) of the test animal's body weight that is required to kill 50% of the test animals. The LD_{50} is qualified by the mode of entry of the substance. "Dermal" refers to skin exposure, while "oral" denotes ingesting the substance. Four general groupings can be made, depending on the LD_{50}.

Relative Toxicity of Insecticides by Acute Oral LD_{50} and Acute Dermal LD_{50}:

Dermal LD_{50} mg/kg	*Oral LD_{50} mg/kg*	*Category*
0-200	0-50	Very toxic: poison
200-2000	50-500	Moderately toxic: warning
2000-20 000	500-5000	Slightly toxic: caution
20 000 and greater	5000 and greater	Relatively nontoxic: should be handled carefully

No hard-and-fast rules exist regarding toxicity. The physical constitution of the individual and the circumstances and duration of the exposure all affect the nature of the toxic effect.

The following table provides comparative examples of oral lethal doses at various toxic levels.

Oral LD_{50} mg/kg	*Probable oral lethal dose for human adult*	
	in cc	*in imperial*
less than 5	0-0.3	a few drops
5-50	0.3-5	1 pinch to 1 tsp.
50-500	5-30	1 tsp. - 2 tbsp.
500-5000	30-500	1 oz. - 1 pt.
5000-15000	500-1000	1 pt. - 1 qt.

The safety values of TLV, STEL, and LD_{50} are only guidelines, and are being steadily lowered as pesticides receive further study. Avoid unnecessary exposure at all times.

It is not within the scope of this Bulletin to provide extensive details on the health-related effects of each compound. Often, specific information on a compound is sparse or unavailable. It is up to the user to ensure that such information is updated regularly. Refer to Appendix 3 for definitions of medical terms. For more information, contact the Pesticide Call Line of Environment Canada with specific questions, or consult other sources (see Bibliography and Appendix 1).

Fumigants

The following five fumigants are not considered suitable for use on museum artifacts or in buildings housing collections, due to safety reasons and/or their effects on materials. They are listed here because they do appear in museum literature. Note that most of these fumigants are not registered or are no longer available for use in Canada.

(a) Hydrogen cyanide. Registration may not cover all museum uses.

(b) Mixture of ethylene dichloride (70%) and carbon tetrachloride (30%). Not registered since 1984; use in Canada illegal.

(c) Mixture of ethylene dibromide (2.8%), carbon tetrachloride (85%), and ethylene dichloride (12.1%). Ethylene dibromide and ethylene dichloride not registered since 1984; use in Canada illegal.

(d) Chloropicrin. Can only be used as a warning gas in other fumigants.

(e) Carbon disulphide (carbon bisulfide). Not registered since 1984; use in Canada illegal.

Dichlorvos

Synonyms
DDVP; dichlorfos; vapona

Chemical Name
2,2-dichlorovinyl dimethyl phosphate

CAS Registry Number
62-73-7

Uses
Household insects; public health pests; stored product pests; veterinary anthelmintic

Formulations
Emulsifiable concentrate; aerosol; impregnated strip; oil concentrate

Chemical Reactivity
Dichlorvos is incompatible with alkaline materials. Dichlorvos hydrolyses to dimethyl hydrogen phosphate and dichloro aceteldehyde.

Reactivity to Materials
Dichlorvos was shown to produce an unacceptable colour change on acid red dyes used in carpets during tests carried out in 1982 by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulators and Distributors Association. Dichlorvos can cause discolouration of textiles. It is corrosive to mild steel and black iron, and can tarnish copper, silver, and brass. Dichlorvos deposits a film on zinc, tin, and lead.

Toxicology
Acute oral LD_{50}: 56-80 mg/kg (rat)
Route of entry: inhalation
Point of attack: cholinesterase inhibition

Remarks
The most common form of dichlorvos is the static dispenser (plastic strip or cylinder), which slowly releases vapour. Dichlorvos in this form is registered for use against flying insects in a room not smaller than 800 cubic feet. The user must take full responsibility for unregistered uses, such as in closed cabinets and display cases.

Precautions
Dichlorvos is very toxic and is easily absorbed through the skin, but reportedly detoxicates very quickly in the body. Seal the dichlorvos in an airtight container with the artifact to be treated to avoid handling the dispenser or breathing the vapour. Never place dichlorvos in contact with an artifact. Individuals working near open cases in which the sticks were hung have suffered from headaches and nausea. Reports indicate that the TLV for this compound may be surpassed even when used as directed. Fatalities from use as a spray or fog at higher concentrations than are present in the strips have been reported. Workers recovering material stored with the sticks should wear rubber gloves, an appropriate respirator, and protective clothing, especially if the sticks have been used extensively in the storage area. Place the sticks in airtight containers and ventilate the area for several hours before working there without respirators.

Because of these dangers, use of dichlorvos in museums should be considered only as a stop-gap measure.

The low vapour pressure of dichlorvos makes it unable to penetrate most materials and ineffective against insect eggs. Because it is not considered effective against insect eggs, it must be applied again at a later date to kill emerged larvae.

Ethylene Oxide

Synonyms
Carboxide; Oxyfume 12; Oxiranne; Penngas; Epoxyethane; ETO; Anprolene

Chemical Name
1,2-epoxyethane

Registration Classification
Not currently registered

Remarks
At present, Agriculture Canada and Health and Welfare Canada are reassessing the registration of ethylene oxide, and are asking manufacturers to provide proof that it can be used safety. U.S. National Toxicology Program tests with rodents confirmed ETO as a carcinogen. It is a known mutagen with a TLV of 1 ppm and an action level of 0.5 ppm in the USA. In Canada, Ontario and Saskatchewan have implemented a TLV of 1 ppm; other provinces will do the same. Furthermore, the effect of ethylene oxide on artifacts is in dispute. Until the reassessment is completed, ethylene oxide should be used only if a major infestation occurs and no other methods of control are possible.

Proper monitoring and safety equipment must be used, and local, provincial, and federal regulatory agencies must be contacted before using ETO. A Canadian Standards Association standard, CAN/CSA-Z314.9-M89, has been written for ETO use in health care facilities.

Even if the fumigation is carried out by a pest control firm at an off-site location, it is the museum's responsibility to ensure that the treated artifacts do not represent a health hazard to staff as a result of out-gassing ethylene oxide. The kinetics of ETO retention are well understood in only a few materials that are routinely fumigated for medical use. Industrial use of ETO has revealed long retention times in some materials.

Methyl Bromide

Synonyms
Bromomethane; Meth-O-Gas; Terr-O-Gas; Maltox

Chemical Name
Bromomethane

Registration Classification
Restricted

CAS Registry Number
74-83-9

Uses
Stored product fumigant; soil fumigant

Reactivity with Materials
Materials containing sulphur—such as woollens, viscose rayons, vinyl, paper (sulphide process), rubber, furs, horse hair, feathers, leather goods, and photographic chemicals—should not be fumigated with methyl bromide. A detailed list of these materials can be obtained from the major manufacturer, Dow Chemical.

Tests have indicated that methyl bromide has no effect on oil paintings on canvas; however, some powdered pigments are affected.

Remarks
Agriculture Canada and Health and Welfare Canada are reassessing the registration of methyl bromide, which is very toxic to humans, and are asking manufacturers to provide proof that methyl bromide can be used safely. In the United States, the proposed TLV has been set at 5 ppm, and methyl bromide is now considered a potential occupational carcinogen. At present, it is recommended that a TLV of 5 ppm be applied to any museum use of this fumigant in Canada.

Until the reassessment is completed, museums should use methyl bromide only if a major infestation occurs and no other methods are available. Proper monitoring and safety equipment must be used, and local, provincial, and federal regulatory agencies must be consulted.

Naphthalene

Synonyms
Moth flakes; mothballs; moth crystals; tar camphor; white tar

Registration Classification
General/domestic use

Uses
Fumigant; repellent

Formulations
Mothballs; moth flakes; moth crystals

Recommended Dosage
See label

Toxicology
TLV: 10 ppm; 50 mg/m^3
STEL: 15 ppm; 75 mg/m^3 (Naphthalene's odour is recognizable at approximately 25 ppm. Saturated air at 25°C contains about 100 ppm naphthalene.)
Route of entry: inhalation of vapour or dust, skin absorption, skin and eye contact
Point of attack: eyes, blood, liver, kidney, skin, red blood cells, central nervous system
Acute oral LD_{50}: 1760 mg/kg

Signs and Symptoms
Upon surface contact: cataracts, ocular irritation, skin irritation, severe dermatitis (in sensitized individuals), systemic poisoning in infants
Inhalation of vapour: headache, confusion, excitement, nausea, vomiting, extensive sweating, dysuria, acute haemolytic anaemia

Individuals with the genetic disease G6PD Deficiency (glucose-6-phosphate dehydrogenase deficiency) are particularly susceptible to haemolytic anaemia, as are newborn infants.

Ingestion or inhalation of high concentrations can produce many of the above symptoms as well as others, such as abdominal pain, bladder irritation, jaundice, haematuria and haemoglobinuria, and kidney failure.

Carcinogenicity and Mutagenicity
Current information indicates that naphthalene is neither a carcinogen nor a mutagen.

Reactivity with Materials
Under some environmental conditions, naphthalene can recrystallize on specimens. It is considered noncorrosive and nonstaining. However, naphthalene in the presence of water produces a reddish-brown discolouration in wool as the result of decomposition products produced by bacterial oxidation of the compound. Naphthalene may dissolve fats in biological specimens (e.g., stuffed animals), resulting in damage.

Remarks
In general, widespread use of naphthalene in museums should be avoided because of health risks. Nonchemical methods should be effective in controlling the insects for which mothballs, flakes, and crystals are normally used.

Naphthalene must be used very carefully. It will be effective only if used in well-sealed, air-tight cases and containers where the vapour concentration can reach equilibrium.

It is of little or no value when simply placed in containers that are opened frequently or near artifacts in open storage.

Naphthalene must not come into direct contact with artifacts; this can be avoided by placing it in open, permeable containers such as cheese cloth bags so that it does not touch the artifacts.

Assuming that an empty container is air-tight, the maximum weight of naphthalene that can remain in vapour form in 1 m^3 of space is 0.43 g at 15°C, 0.56 g at 20°C, and 0.69 g at 25°C. Three to four times the above amounts should provide adequate term protection, depending on the temperature and on the air-tightness of the container.

The length of time required for naphthalene to kill various stages of museum pests is not known. Even in sealed containers, it is not certain that the egg stage will be killed. To be safe, an exposure at room temperature of not less than two and not more than six weeks should be adhered to in order to be certain of killing hatching insects. Following exposure, carefully inspect the artifact to ensure that the fumigation was effective. Discovery of live insects will dictate further exposure or an alternate method.

Herbaria are often cited as examples of where some form of regular fumigation is required. However, such intensive use of a fumigant poses a health hazard. Good housekeeping, well-designed cases, and maintenance of a proper environment will reduce the possibility of infestation of herbaria and the need for regular fumigation. Many herbaria have already adopted the use of low temperatures as an alternate control method.

Ventilate areas around cases or containers holding naphthalene to prevent build-up of vapour outside the cases, particularly if they are in a work or public area. Cases containing naphthalene should be opened as little as possible. If a case must be opened, wear gloves, goggles, and a respirator, and keep a fan operating nearby to dilute the naphthaline vapour. Do not work in a storage room in which naphthalene has been used extensively without wearing an appropriate cartridge-type respirator or first ventilating the room to the outdoors. Prolonged aeration of an artifact may be required because naphthalene odour lingers. Work on an artifact smelling strongly of naphthalene should be carried out under a fumehood, in a well-ventilated area, or while wearing a cartridge-type respirator.

Paradichlorobenzene

Synonyms
P-dichlorobenzene; p-DCB; 1,4-DCB; PDB; PDCB; PARA; Para-Di; Paracide; Paradow

Chemical Name
1,4-dichlorobenzene

Registration Classification
General/domestic use

CAS Registry Number
Product-specific

Uses
Fumigant; repellent

Formulations
Mothballs; moth flakes; moth crystals

Recommended Dosage
See label

Toxicology
TLV: 75 ppm; 450 mg/m^3
STEL: 100 ppm; 675 mg/m^3. Paradichlorobenzene's odour is detectable between 15 and 30 ppm.
Acute oral LD_{50}: 1000-7595 mg/kg. The large range is due to several species having been included.
Acute dermal LD_{50}: 2000 mg/kg
Route of entry: inhalation, ingestion, eye and skin contact
Point of attack: liver, respiratory system, eyes, kidneys, skin

Signs and Symptoms
Headaches, eye irritation, periorbital swelling, profuse rhinitis, anorexia, numbness, clumsiness (loss of coordination), nausea, vomiting, weight loss, jaundice, liver cirrhosis, kidney damage, haemolytic anaemia

Individuals with pre-existing pathology (hepatic, renal, central nervous system, blood), with metabolic disorders, or who are taking drugs (hormones or otherwise metabolically active) are at an increased risk from exposure to this compound.

Carcinogenicity and Mutagenicity
Insufficient evidence is available for regulatory agencies to assess the risk of this compound. Only one study has suggested an association between leukemia and exposure to dichlorobenzenes.

Reactivity with Materials
Paradichlorobenzene can affect zinc white, lithopone, and scarlet pigments. It also alters some cellulose acetate dyes. Polystyrene foams shrink excessively. Plastics such as styrene and cellulose nitrate are softened, as are some resins. Paradichlorobenzene has caused slight discolouration of ultramarine, slight yellowing of paper, and fading of ink, believed to be due to the chlorine component of the paradichlorobenzene.

Remarks
This product has been used in a manner similar to naphthalene and is reportedly a more effective insecticide, though it poses more serious problems.

Paradichlorobenzene is far more volatile than naphthalene, and is far more difficult to keep from sublimation in hot weather. Because of its volatility, a rapid loss of vapour occurs from museum cases, etc., resulting in a substantial concentration of vapour in the surrounding air, which poses a health hazard. Assuming that an empty container is air-tight, the maximum weight of paradichlorobenzene that can remain in vapour form in 1 m^3 of space is 3.18 g at 15°C, 5.14 g at 20°C, and 7.89 g at 25°C. Three or four times these amounts should provide adequate term protection, depending on temperature and air-tightness of the container. An exposure of approximately two weeks is sufficient to kill the larval stages of the black carpet beetle and the common clothes moth; information on other stages and other species is not available. The precautions outlined for naphthalene also apply to the use of paradichlorobenzene.

Do not use paradichlorobenzene unless the artifacts are known to be unaffected by it or the exposure of artifacts to the vapour can be avoided.

Phosphine

Synonyms
Phostoxin; Celphos; Delicia Gastoxin; Detio-Gas-Ex-T; Ex-B

Chemical Name
Hydrogen phosphide

Registration Classification
Restricted

CAS Registry Number
7803-51-2

Uses
Agricultural commodity fumigant; not registered for use in museums or on clothes moths, furs, or furniture

Formulations
Aluminium or magnesium phosphide powder or pellet

Phosphine reacts with atmospheric moisture to generate phosphine gas. Some formulations combine aluminium phosphide with ammonium carbamate, the latter of which decomposes into ammonia and carbon dioxide.

Recommended Dosage
See label

Toxicology
TLV (time-weighted average): 0.3 ppm; 0.4 mg/m^3
TLV-STEL: 1 ppm; 1 mg/m^3
Immediately dangerous at 200 ppm according to the National Institute of Occupational Safety and Health/Occupational Safety and Health Association (NIOSH/OSHA).
Route of entry: inhalation
Point of attack: respiratory system is most sensitive; effects have also been noted in brain, kidneys, liver, and heart.

Signs and Symptoms
Headache, enlarged pupils, vertigo, thirst, loss of appetite, diarrhoea, vomiting, lassitude, immobility, ataxia, pallor, epileptiform convulsions, apnea, cardiac arrest

Carcinogenicity and Mutagenicity
Potential for human chromosome damage has been reported.

Reactivity with Materials
Spontaneously flammable in presence of P_2H_4; reacts violently with oxygen, nitrates, and halogens

Remarks
Phosphine has an odour of decaying fish with an odour threshold or 2 ppm. Its lower explosion limit has been reported at 1.79% by volume in air. Phosphine is generally used in atmospheric fumigation, and can be effective in controlling all stages of insect life. Phosphine has a low solubility in water, oils, and fats. At elevated temperature and humidity, phosphine can cause corrosion of copper, copper alloys, silver, and gold.

Sulphuryl Fluoride

Synonyms
Vikane; sulphuric oxyfluoride

Chemical Name
Sulphuryl fluoride

Registration Classification
Not registered in Canada

Uses
Fumigant

Formulations
Pressurized cylinders

Recommended Dosage
See label

Toxicology
TLV: 5 ppm; 20 mg/m^3
STEL: 10 ppm; 40 mg/m^3
Route of entry: inhalation, skin and eye contact
Point of attack: eyes, respiratory system, central nervous system, kidneys

Signs and Symptoms
In humans: nausea, vomiting, abdominal pain (cramps), itching, pruritus, conjunctivitis, rhinitis ("hay fever")

In animals: tremors with subsequent severe convulsions, pulmonary edema, kidney and lung injury; evidence of fluorosis in the teeth of mice

Reactivity with Materials
The results of studies on the effects of sulphuryl fluoride on artifact material are published (Burgess and Binnie 1990).

No objectionable colour, odour, or corrosive reaction has been reported from the use of sulphuryl fluoride on photographic supplies, metals, paper, leather, rubbers, plastics, cloth, wallpaper, tapestries, ancient fabric, aged wood, silver, pewter, and gold artifacts. When basement rooms are fumigated, forced air ventilation may be necessary to remove residual sulphuryl fluoride.

When sulphuryl fluoride condenses during atmospheric fumigation, damage to wallpaper and corrosion of brass door handles have been observed.

Although sulphuryl fluoride is relatively nonreactive with most materials, it does react with strong bases and is slightly soluble in organic solvents, vegetable oils, and Stoddard Solvent (Dow Chemical 1983). A problem of residual fluorides has been found in some proteinaceous foodstuffs such as cheese and meat, likely due to fat content (Monro 1964). The extent to which this would occur in museum materials such as leather or oiled skins is not known.

Sulphuryl fluoride is stable at ambient temperatures, but electric elements, open flames, and steam can react with the vapour to form toxic and corrosive fumes.

Remarks
Sulphuryl fluoride is a very toxic gas with good penetrating powers and rapid aeration from fumigated material. Dow Chemical, the manufacturer, considers a period of less than 24 hours adequate for aeration following atmospheric fumigation.

Sulphuryl fluoride has been found effective on structural pests (e.g., drywood termites, old house borers, powder post beetles) and household pests (e.g., clothes moths, carpet beetles). It is toxic to all post-embryonic stages of insects, but the eggs of many are resistant, requiring increased dosages.

Sulphuryl fluoride is not registered for use in Canada. It is registered for use in the United States for structural fumigation and for use in fumigation chambers. Additional information can be obtained from the manufacturer, Dow Chemical, with respect to operating procedures and safety devices, including the necessary monitoring equipment.

Organochloride Insecticides

The following organochloride insecticides, representing the most commonly available insecticides of this group, are not considered suitable for use on museum artifacts or in buildings housing collections because of their effects on materials and/or health hazards (Dawson 1988):

- Aldrin (Octalene, Compound 118, HHDN)
- Benzene Hexachloride
- Chlordane (Velsicol 1068, Octachlor)
- Chlordecone (Kepone)
- Dichloro-diphenyl-trichloroethane (DDT)
- Dieldrin (Octalox, HEOD)
- Lindane (Gamma-BHC, Gamma-HCH, Gammexane, Forlin, Gamophex)
- Methoxychlor (Marlate, DMDT)
- Chlorophenols (particularly pentachlorophenol)

Organophosphates

Organophosphates are primarily contact and stomach insecticides, although their vapour may have a fumigant action. Though many organophosphate insecticides are more toxic than the organochlorides, they are frequently used at extremely low concentrations, thus greatly lessening the danger in applying them. Organophosphate insecticides have been found to react with red dyes in carpeting, particularly when over-applied under conditions of high RH. Under normal circumstances, staining is believed to occur.

Chlorpyrifos

Synonyms
Dursban; Lorsban; Dowco 179; chlorpyriphosethyl; ENT 27311

Chemical Name
0,0-diethyl *0*-(3,5,6-trichloro-2-pyridyl) phosphorothioate

Registration Classification
Product-specific

CAS Registry Number
2921-88-2

Uses
Contact insecticide

Formulations
Solution; dust; granules; spray concentrate; emulsifiable concentrate

Recommended Dosage
See label

Toxicology
TLV: 0.2 mg/m^3 (skin)
STEL: 0.6 mg/m^3
Acute oral LD_{50}: 82-163 mg/kg (rat)
Acute dermal LD_{50}: 2000 mg/kg (rabbit)

Route of entry: skin absorption, inhalation of dusts, ingestion
Point of attack: respiratory system, skin, central nervous system, cardiovascular system

Signs and Symptoms
The general signs and symptoms of organophosphate insecticide poisoning are comparable to those indicated for diazinon. Exposure to chlorpyrifos can result in a significant decrease in plasma and red blood cell cholinesterase levels, and can cause cholinergic symptoms; it has little capacity to cause systemic injury. Chlorpyrifos is rapidly metabolized in the animal body.

Effects on Reproduction
No evidence of teratologic or reproductive effects were apparent in studies on rats.

Reactivity with Materials
Chlorpyrifos is corrosive to copper and brass. Tests carried out in 1982 by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulators and Distributors Association found that when chlorpyrifos was used on carpets containing acid red, disperse red, or telon red dyes, slight to moderate colour changes were observed on some of the acid red or disperse red dyes. Therefore, if chlorpyrifos is used near artifacts, they should be covered with protective polyethylene.

Remarks
Chlorpyrifos is moderately toxic to humans.

Chlorpyrifos has poor knockdown (immediate response) and flushing (driving insects out of harbourages) capabilities, and is often used with other insecticides that have these capacities.

Indoors, the residual effects of chlorpyrifos last for about 30 days. It has a longer residual life on nonporous materials than have most insecticides. A spray or brush application on wood penetrates to a depth of approximately 6 mm ($^1/_4$ inch), and can persist for several years.

Chlorpyrifos is stable when protected from ultraviolet (UV) light, temperature extremes, and moisture. It is volatile enough to form deposits on nearby untreated surfaces.

Follow the precautions given in Section 6 of this Technical Bulletin and the warnings of the manufacturer.

Diazinon

Synonyms
Spectracide; ENT 19507; Basudin; Diazitol; Neocidol; Nucidol

Chemical Name
0,0-diethyl, *0*-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate

Registration Classification
Product-specific

CAS Registry Number
333-41-5

Uses
Contact insecticide

Formulations
Wettable powder, granules, emulsifiable concentrate, oil solutions, dust, microencapsulation

Recommended Dosage
See label

Toxicology
TLV: 0.1 mg/m^3 (skin)
STEL: 0.3 mg/m^3
Acute oral LD_{50}: 34-250 mg/kg
Acute dermal LD_{50}: 379-455 mg/kg
Route of entry: ingestion, inhalation, dermal
Point of attack: respiratory system, skin, central nervous system (cholinesterase inhibitor), cardiovascular system

Signs and Symptoms
Mild: anorexia and nausea, weakness, dizziness, blurred vision, miosis
Moderate: vomiting, abdominal cramps and diarrhoea, salivation, lacrimation, sweating, dyspnea, substernal tightness, slow pulse, tremors of the extremities, muscular cramps, ataxia
Severe: fever, cyanosis, pulmonary edema, areflexia and loss of sphincter control, convulsions, coma, heartblock, shock, respiratory failure

Delayed paralysis may be permanent. Cholinesterase inhibition may be very high, depending on exposure. Individuals with active kidney or liver diseases should not be exposed to diazinon.

Carcinogenicity and Mutagenicity
Unknown. Recent U.S. National Toxicology Program tests with rodents did not indicate any carcinogenic activity.

Reactivity with Materials
Damage from solvents may occur. Tests carried out in 1982 by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulation and Distributors Association found that when diazinon was used on carpets containing acid red, disperse red, or telon red dyes, very slight to slight colour changes occurred in some of the acid red and disperse red dyes. Therefore, if diazinon is used near artifacts, they should be covered with protective polyethylene.

Remarks
Diazinon is a moderately to very toxic insecticide to fish, birds, and bees.

It has a shorter residual life on non-absorptive surfaces than on absorptive surfaces. The spray remains potent for 30 days or more when used indoors.

Follow the general precautions in Section 6 of this Technical Bulletin and the manufacturer's warnings.

Malathion

Synonyms
Cythion; Mercaptothion; ENT 17034; Malathiazol; Malathiazoo

Chemical Name
S-1,2-bis(ethoxycarbonyl) ethyl 0,0-dimethyl phosphorodithioate

Registration Classification
Product-specific

CAS Registry Number
121-75-5

Uses
Contact insecticide

Formulations
Wettable powder; dust; emulsifiable concentrate

For indoor use, the formulation should contain the premium grade of malathion, since the regular grade has an offensive odour.

Recommended Dosage
See label

Toxicology
TLV: 10 mg/m^3 (skin)
Acute oral LD_{50}: 885-2100 mg/kg
Acute dermal LD_{50}: 4100 mg/kg (rabbit)
Route of entry: inhalation of vapour, skin absorption, ingestion, skin and eye contact
Point of attack: respiratory system, liver, blood cholinesterase, central nervous system, cardiovascular system, gastrointestinal system

Reactivity with Materials
Malathion is corrosive to iron, steel, tin plate, lead, and copper. Tests carried out in 1982 by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulators and Distributors Association using malathion on carpets containing acid red, disperse red, or telon red dyes found unacceptable colour changes on acid red and disperse red dyes. Malathion's effects on other materials are unknown. To be safe, it should not be used near artifacts unless they are covered with polyethylene.

Signs and Symptoms
Increased bronchial secretion, excessive salivation, nausea, vomiting, excessive sweating, miosis, muscular weakness, and fasciculation are induced by the inhibition of functional acetyl cholinesterase in the central nervous system. Allergic sensitization of the skin can occur. Malathion is more toxic to children when inhaled than when swallowed. The general symptoms for organophosphate insecticides are comparable to those listed for diazinon.

Carcinogenicity and Mutagenicity
National Cancer Institute tests have been negative for carcinogenicity of malathion. It is an experimental equivocal tumorigenic agent, and is an experimental mutagen.

Effects on Reproduction
Malathion is a potential teratogen, and is highly toxic if ingested.

Remarks
Malathion is one of the least toxic organophosphates. However, its effects on humans are being re-examined. This insecticide should be used very carefully. Follow the warnings of the manufacturer and the precautions in Section 6 of this Technical Bulletin.

Malathion has a brief to moderate residual life and is biodegradable, breaking into compounds that do not affect the environment.

Carbamates

Carbamates are derivatives of carbamic acid. These compounds are generally suspected of being carcinogens of the lungs and of organs involved in blood production. They are less volatile than the organophosphates, and present less risk of vapour poisoning. Although they are cholinesterase inhibitors, symptoms may appear rapidly, thereby warning workers before a dangerous dose is absorbed. Chronic or cumulative effects are improbable.

Bendiocarb

Synonyms
Ficam

Chemical Name
2,2-dimethyl-1,3-benzodioxol-4-yl methylcarbamate

Registration Classification
Restricted

CAS Registry Number
22781-23-3

Uses
Contact and stomach insecticide

Formulations
Dust; wettable powder

Recommended Dosage
See label

Toxicology
Acute oral LD_{50}: 143-179 mg/kg
Acute dermal LD_{50}: 1000 mg/kg
Route of entry: inhalation, skin or eye contact, skin absorption, ingestion
Point of attack: respiratory system, skin, central nervous system, cardiovascular system

Signs and Symptoms
The symptoms for bendiocarb are also the general symptoms for carbamates: headache, dizziness, blurred or dark vision, constriction of pupils, salivation, profuse sweating, lassitude, muscle incoordination, nausea, vomiting, diarrhoea, epigastric pain, tightness in the chest, twitching, tremor, incontinence, slow heart beat, and wheezing.

Reactivity with Materials
Since bendiocarb formulations are normally applied dry or in water, damage to surfaces is not expected unless the surfaces are sensitive to water. This fact is supported by the tests carried out in 1982 by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulators and Distributors Association, which found no significant staining problem when bendiocarb was used on carpets containing acid red, disperse red, and telon red dyes.

Remarks
Bendiocarb's activity can persist for weeks or months, depending on environmental conditions and other circumstances.

Because the dust does not have a fumigant action, the dangers in using this insecticide are reduced at ambient temperatures.

Observe the manufacturer's warnings and the precautions outlined in Section 6 of this Technical Bulletin.

Carbaryl

Synonyms
Sevin

Chemical Name
N-methyl-1-naphthyl-carbamate; 1-naphthyl methylcarbamate

Registration Classification
Product-specific

CAS Registry Number
63-25-2

Uses
Contact and stomach insecticide

Formulations
Wettable powder; sprayable powder; dust; granules; flowable and emulsifiable concentrations

Recommended Dosage
See label

Toxicology
TLV: 5 mg/m^3
STEL: 10 mg/m^3
Acute oral LD_{50}: 500-850 mg/kg
Acute dermal LD_{50}: greater than 4000 mg/kg
Route of entry: inhalation, skin or eye contact, skin absorption, ingestion
Point of attack: respiratory system, skin, central nervous system, cardiovascular system

Signs and Symptoms
Mild: headache, anorexia and nausea, weakness, dizziness, blurred vision, miosis
Moderate: vomiting, abdominal cramps and diarrhoea, salivation, lacrimation, sweating, dyspnea, substernal tightness, slow pulse, tremors of the extremities, muscular cramps, ataxia
Severe: fever, cyanosis, pulmonary edema, areflexia and loss of sphincter control, convulsions, coma, heartblock, shock, respiratory failure

Permanent effects have not been reported. Accumulation in mammalian tissue has not been found.

Carcinogenicity and Mutagenicity
Carbaryl is a carcinogen in rats when ingested, and is an experimental mutagen.

Effects on Reproduction
Carbaryl is a teratogen in rats, dogs, rabbits, and guinea pigs via the oral route.

Reactivity with Materials
Carbaryl is noncorrosive. Care must be taken for solvent effects. Because of its residual nature, carbaryl should not come into contact with artifacts.

Remarks
Carbaryl is considered to be moderately toxic to humans, and is toxic to bees.

Carbaryl has a moderate residual action ranging from several days to three to four months on protected surfaces. It is stable to heat and light.

Follow the precautions in Section 6 of this Technical Bulletin, and observe the manufacturer's warnings.

Propoxur

Synonyms
Baygon; ENT 25671; PHC; Blattanex; Undex

Chemical Name
2-isopropoxyphenyl methylcarbamate

Registration Classification
Product-specific

CAS Registry Number
114-26-1

Uses
Contact insecticide

Formulations
Emulsifiable concentrate; pressurized spray and solution

Recommended Dosage
See label

Toxicology
TLV: 0.5 mg/m^3
STEL: 2.0 mg/m^3
Acute oral LD_{50}: 83-128 mg/kg
Acute dermal LD_{50}: greater than 2400 mg/kg
Route of entry: inhalation, ingestion, skin or eye contact, skin absorption
Point of attack: respiratory system, skin, central nervous system, cardiovascular system

Signs and Symptoms
See the general symptoms for carbamates listed under bendiocarb. The signs and symptoms of propoxur are caused by its cholinesterase inhibition. Symptoms are transitory; a single oral dose of 1.5 mg/kg produces gastrointestinal symptoms that disappear within two hours of ingestion. In very large doses, propoxur can cause tremors, convulsions, and death. Asthmatics may experience respiratory problems if exposed to propoxur. Sensitization to propoxur can occur, which increases the risk of exposure.

Carcinogenicity and Mutagenicity
Unknown (see general comments on carbamates)

Reactivity to Materials
Manufacturers indicate that this insecticide should not be used on carpets, drapes, wallpaper, or similar materials that might be stained. Excessive wetting of plastics, rubber, asphalt, and floor coverings should be avoided. If propoxur must be used near artifacts, cover them with protective polyethylene.

Tests carried out by the Carpet and Rug Institute with the National Pest Control Association and the United Pesticide Formulators and Distributors Association using propoxur on carpets containing acid red, disperse red, or telon red dyes found no significant colour changes. Of 18 dyes tested, only two acid red dyes showed change, and in each case the change was recorded as very slight.

Propoxur is moderately toxic to humans and is toxic to fish, birds, and other wildlife.

Propoxur has a good flushing action and a good knock-down effect. Its residual effectiveness indoors is up to 45 days.

Follow the general precautions for specific applications in Section 6 of this Technical Bulletin and the warnings of the manufacturer.

Botanicals

Many organic insecticides are derived from plants. They are of value because of their contact action, because they decompose quickly when exposed to light and air, and because they essentially have no residual effect. Synthetic botanicals, referred to as synthetic pyrethrins or pyrethroids, have been produced with greater stability and insect toxicity than their naturally occurring equivalents. In general, botanicals and the synthetic pyrethroids have low toxicity to humans, but should be assessed individually, since some in this group are far more toxic than others. Following is a detailed discussion of the most common insecticide of the group — pyrethrum.

Pyrethrum

Synonyms
Pyrethrins (pyrethrum is a mixture of six toxic chemicals from pyrethrum flowers, collectively referred to as pyrethrins)

Registration Classification
General use

Uses
Contact insecticide

Formulations
Pressurized sprays; dusts; oil solution; microencapsulation

Recommended Dosage
See label

Toxicology
TLV: 5 mg/m^3
STEL: 10 mg/m^3
Acute oral LD_{50}: 584-900 mg/kg (rat)

Acute dermal LD_{50}: greater than 1500 mg/kg (rat)
Route of entry: inhalation, ingestion, eye and skin contact
Point of attack: respiratory system, skin, central nervous system

Signs and Symptoms
Skin irritation and allergic dermatitis, asthmatic breathing, headache, tinnitus, nausea and vomiting, excitement, diarrhoea, incoordination, tremors, convulsions, prostration, anaphylactic reactions

Persons sensitive to ragweed will be the most prone to pyrethrin poisoning. Sensitization to pyrethrins may be permanent. Sensitized individuals must be removed from further exposure.

Reactivity with Materials
Unknown; possibility of solvent effects

Remarks
Pyrethrins are among the safest insecticides because they present little danger to mammals. However, they are toxic to fish.

Because pyrethrins are unstable and break down chemically to nonpoisonous compounds, there is little danger from residues.

Pyrethrins are often combined with synergists (e.g., piperonyl butonide), which are chemicals used to increase their effectiveness. Although quick-acting and providing a rapid knockdown of insects, pyrethrins do not always kill all of the insects that are knocked down. They are often used to flush insects out of cracks and crevices; because of this flushing action, pyrethrins are often combined with more residual insecticides.

Formulations with silica gel, diatomaceous earth, or microencapsulation help to extend pyrethrum's persistence from as little as several hours to up to 90 days.

Do not permit artifacts to come in direct contact with insecticides containing pyrethrins or pyrethroids.

Follow the precautions set out in Section 6 of this Technical Bulletin, and observe the manufacturer's warnings.

Inorganics

Inorganics were among the first insecticides. By nature, they tend to be both persistent and slow acting. While some are very toxic to man, others have a low toxicity. Inorganic insecticides, such as arsenicals (various compounds of the element arsenic) and boric acid (borax), are stomach poisons, while diatomaceous earth and silica aerogel are desiccant insecticides.

Amorphous Silica Gel

Synonyms
Amorphous hydrated silica; silica aerogel; silica xerogel; silica gel; silicic acid; Dri-die 67

Chemical Name
Silicon dioxide

Registration Classification
Product-specific

CAS Registry Number
7631-86-9

Uses
Desiccant insecticide; often combined with pyrethrins

Formulations
Dust; pressurized spray

Recommended Dosage
See label

Toxicology
TLV: 80 mg/m^3
Acute oral LD_{50}: 22,500 mg/kg (rat)
Route of entry: inhalation, ingestion
Point of attack: respiratory system

Signs and Symptoms
Silica gel in its pure, unaltered form is considered nontoxic. However, silica gel may contain other crystalline varieties of silica that are fibrogenic (capable of causing fibrosis). The information presented on diatomaceous earth should be consulted. Avoid skin contact, since the silica gel can cause irritation.

Reactivity with Materials
Specific information is not available; refer to "Dusting" in Section 5 of this Bulletin for general comments

Remarks
The silica gels used in insecticides have a very low bulk density and a high porosity. For example, Dri-die 67 has a density of 2 kg/28 cu dm (4.5 lb per cubic foot). In humid air, the death of insects by dehydration is retarded. When pyrethrins are impregnated into the silica gel, the normal persistence of the pyrethrins is extended.

Because of the physical characteristics of silica gel dust, it can be forced into areas and voids where treatment with a liquid is not effective.

Observe the safety precautions noted under "Dusting" in Section 5 of this Technical Bulletin and the warnings of the manufacturer.

Arsenic Insecticides

Inorganic arsenic pesticides are no longer registered for use in Canada; their use is, therefore, illegal.

In the past, arsenicals were widely used not only as insecticides but also as herbicides and rodenticides. Their main use in museums was in the preservation of animal and bird skins in taxidermy specimens. In taxidermy, arsenic trioxide (arsenous oxide, white arsenic) and sodium arsenite were the main compounds used.

Opinions vary regarding the effectiveness of the arsenicals used in taxidermy specimens. The toxicity of arsenicals, their questionable effectiveness, and the development of new insecticides have led to discontinued use of arsenicals, particularly in taxidermy. However, arsenicals are very persistent compounds that reside in treated specimens, sometimes appearing as a fine, white dust. Arsenicals are thought by some experts to migrate out of treated skins over time.

Most people are well aware of arsenic's dangerous effects if it is ingested. However, many do not know that arsenic also presents a serious health hazard if inhaled or absorbed by the skin. Early signs of such poisoning are loss of appetite, cramps, nausea, headache, and dizziness. Kidney and nervous disorders may develop. Arsenic is a recognized carcinogen of the skin, lungs, and liver, and has been linked with cancers of the mouth, oesophagus, larynx, bladder, and paranasal sinus. In addition to the cancerous changes, itching and other skin problems can develop.

While the actual hazard level posed by artifacts previously treated with arsenicals is difficult to ascertain, four guidelines should be observed:

(a) If a whitish powder is evident on natural history specimens or on other artifacts, identify the powder. If not an arsenical, the dust could be borax, boric acid, DDT, or another such substance. Information on identifying arsenic can be obtained from CCI. In the interim, treat such artifacts as though the dust is toxic.

(b) Handle or move artifacts known or suspected to contain arsenic as little as possible. If handling is necessary, wear disposable gloves, a dust mask, a lab coat, and coveralls. As a further precaution, cover or bag the specimens with polyethylene to prevent inadvertent contact. Attach a warning note.

(c) Isolate contaminated artifacts or those suspected of contamination so that the general public, particularly children, will not come into contact with them. Remove natural history specimens, especially fur-bearing animals, from touch-and-feel displays unless they are known not to contain arsenic or other toxic preservatives.

(d) Contact CCI for advice before attempting to remove any powder.

Boric Acid

Synonyms
Boracic acid; borsaure; NC1-C56417

Examples of insecticides containing high percentages of boric acid include Borid, Boron #10, Boron #101, Drax, ENUF, Mop Up, Perma-dust, Relyon 2 100, Rid A Roach, Roach Kil, and Roach Prufe.

Chemical Name
Orthoboric acid

Registration Classification
Product-specific

Uses
Stomach poison insecticide; contact insecticide

Formulations
Dust; gel; in a water-based spray

Recommended Dosage
See label

Toxicology
TLV: none established. The value given for boric oxide is 15 mg/m^3, while the American Conference of Governmental Industrial Hygienists proposes 10 mg/m^3. The TLV for borax (decahydrate sodium salt of boric acid) is 5 mg/m^3 .
Acute oral LD_{50}: 2660 mg/kg
Route of entry: inhalation, ingestion, skin absorption (via damaged skin, cuts, scratches, etc.)
Point of attack: central nervous system, skin, gastrointestinal tract, developing foetus

The lowest reported lethal dose by an oral route for a 150-pound (68 kg) man is 0.5 ounce (about three teaspoons); 0.15 ounce (about one teaspoon) is lethal for a 10-pound (4.5 kg) infant. No known deaths have been reported from the use of boric acid as an insecticide.

Signs and Symptoms
Depression of circulation, nausea, persistent vomiting, abdominal pain, diarrhoea, possible headache and weakness, temperature becoming subnormal, a red body rash followed by peeling; if severe, profound shock and coma

Carcinogenicity and Mutagenicity
Potential mutagen

Effects on Reintroduction
Experimental teratogen

Reactivity with Materials
Specific information is not available. Refer to "Dusting" in Section 5 of this Technical Bulletin for general comments.

Remarks
Boric acid is a stomach poison used against crawling insects; it can be consumed by the insect during grooming, or be absorbed through the body wall of the insect. Standard boric acid formulations are very slow acting, resulting in a high level of kill within 2 to 10 days, while others claim a high level of kill within 12 to 48 hours.

In dry, clean, undisturbed areas, boric acid can remain effective for up to 12 months. To prevent caking in areas of high relative humidity, many formulations contain an anti-caking agent such as sodium sulphate, which has a low-level toxicity reflected by an oral LD_{50} of 5989 mg/kg. Claims by some manufacturers of boric acid formulations lasting for years have not been adequately substantiated.

Dust formulations of boric acid can be forced into areas and voids where treatment with a liquid is not effective. Remove any dust visible following application. Although the toxicity of boric acid has been compared to that of aspirin, most formulations contain a high concentration of boric acid, ranging from 64 to 99 per cent by weight of boric acid.

Do not apply boric acid directly to artifacts or in areas where it will be contacted. Apply the safety precautions given in Section 5 of this Technical Bulletin for "Dusting", and observe the manufacturer's warnings. If extensive application is necessary, hire a licensed pest control operator.

Borax (sodium borate decahydrate) has been used in natural history specimens as a safer replacement for arsenic. The same health-related effects given for boric acid can generally be applied to this compound. Although borax is safer than arsenic, artifacts known or suspected to contain borax should be dealt with in the same manner outlined for arsenic. Do not use these artifacts in touch-and-feel displays, particularly if young children are participating.

Diatomaceous Earth

Synonyms
Infusorial earth; siliceous earth; fossil flour; kieselguhr; Celite; Super-Cel

Registration Classification
Product-specific

Uses
Desiccant insecticide

Formulations
Dust; often combined with pyrethrins

Recommended Dosage
See label

Toxicology
TLV: 1500 mg/m^3
Route of entry: inhalation, ingestion
Point of attack: respiratory system

Signs and Symptoms
Pain in the chest, cough with little or no expectoration, dyspnea, reduced thoracic excursion, sometimes cyanosis and fatigue after slight exertion

These symptoms are the result of a disabling pulmonary fibrosis known as silicosis, a form of pneumoconiosis. Avoid contact with diatomaceous earth, since it can cause irritation.

Reactivity with Materials
Specific information is not available. Refer to "Dusting" in Section 5 of this Technical Bulletin for general comments.

Remarks
Diatomaceous earth is produced from the remains of diatoms (single-celled aquatic dwellers with siliceous cell walls) deposited millions of years ago. When pyrethrins are impregnated into the diatomaceous earth, the normal persistence of the pyrethrins is extended. Diatomaceous earth can be forced into areas and voids where treatment with a liquid is not effective.

Diatomaceous earth should not be applied directly on artifacts or in areas where it will be disturbed or contacted by individuals. During application, take the safety precautions outlined in "Dusting" in Section 5 of this Technical Bulletin to avoid inhalation and contact with the diatomaceous earth, and observe the manufacturer's warnings.

Appendix 1

Sources of Information
Questions regarding museum pests and insect control can be directed to the following sources:

Canadian Conservation Institute
1030 Innes Road
Ottawa ON K1A 0M5
Tel.: (613) 998-3721
Fax: (613) 998-4721

or

Pesticide Call Line
Pesticides Directorate
Agriculture Canada
2200 Walkley Road, First Floor
Ottawa ON K1A 0C6
Tel.: (800) 267-6315

B.C. Ministry of Agriculture
Douglas Building
Victoria BC V8W 2Z7

Crop Protection and Pest Control Branch
Alberta Department of Agriculture
Edmonton AB T5K 2C8

Pest Control Specialist
Production and Marketing Branch
Saskatchewan Department of Agriculture
Regina SK S4S 0B1

Provincial Entomologist
Manitoba Department of Agriculture
711 Norquay Building
Winnipeg MB R3C 0P8

Provincial Entomologist
Department of Environmental Biology
University of Guelph
Guelph ON N1G 2W1

Communications Québec
Tel.: (800) 363-9883

Chief
Division of Entomology
Quebec Department of Agriculture
Quebec QC G1P 3W8

Plant Industry Branch
N.B. Dept. of Agriculture and Rural Development
Fredericton NB E3B 5H1

Provincial Entomologist
N.S. Department of Agriculture and Marketing
Kentville NS B3J 2M4

Director of Production
Dept. of Rural Agriculture & Northern Development
St. John's NF A1C 6C9

P.E.I. Department of Agriculture and Forestry
Box 1600
Charlottetown PE ClA 7N3

National Identification Service
Agriculture Canada
K.W. Neatby Building
Central Experimental Farm
Ottawa ON K1A OC6

Entomologists at local universities and federal or provincial experimental stations may also be able to provide assistance in identifying insect pests.

Appendix 2

Fumigation Chamber Manufacturers
The following companies represent the major manufacturers of fumigation chambers for museums and galleries.

Kewaunee Scientific Equipment Corp.
Special Products Division
Adrian MI 49221
U.S.A.

Agent in Canada:
Sciquip Ltd.
2333 Millrace Court
Mississauga ON L5N 1W2

John Mohr and Sons
Engineers and Contractors
General Office and Plant
3200 E. 96th Street
Chicago IL 60617
U.S.A.

Vacudyne Altair
375 E. Joe Orr Road
Chicago Heights IL 60411
U.S.A.

Slack Associates, Inc.
540 S. Longwood St.
Baltimore MD 21223-2797
U.S.A.

Appendix 3

Glossary of Medical Terms
The following glossary is provided to help in understanding some terms used to describe the possible effects of insecticides.

anaphylactic reactions
reactions brought about due to an extreme sensitivity to foreign protein or other material (e.g., the reactions of an individual suffering from hay fever), which can range from mild to severe.

anorexia
loss of appetite.

areflexia
absence of reflexes.

ataxia
inability to perform coordinated muscular movement.

carcinogen
any agent that incites development of a carcinoma or any other sort of malignancy.

cholinergic
relating to nerve cells or fibres that employ acetylcholine as a neurotransmitter.

cholinesterase
an enzyme found in blood and in other tissues that catalyses hydrolysis of choline esters including acetylcholine.

conjunctivitis
inflammation of the conjunctiva (the mucous membrane covering the eyeball and lining the eyelids).

cyanosis
a bluish colouration in the skin and mucous membranes due to deficient levels of oxygen in the blood.

dehydrogenase
those enzymes that catalyse removal of hydrogen from certain metabolites (hydrogen donors) and transfer it to other substances (hydrogen acceptors); the first metabolite is oxidized, the second is reduced.

dyspnea
shortness of breath.

dysuria
painful urination.

epigastric
relating to the epigastrium (the region of the abdomen located between the costal margins and the subcostal plane).

fasciculations
involuntary contractions or twitchings of groups (fasciculi) of muscle fibres; a coarser form of muscular contractions than fibrillation.

fibrosis
formation of fibrous tissue as a reparative or reactive process as opposed to the formation of fibrous tissue that is a normal constituent of an organ or tissue.

glucose-6-phosphate
an ester of glucose with the functional phosphate group attached to carbon atom 6.

glucose-6-phosphate dehydrogenase deficiency (G6PD deficiency)
a deficiency of the enzyme that catalyses the oxidation of glucose-6-phosphate by NADP (nicotinamide adenine dinucleotide phosphate).

haemolytic anaemia
a decrease in the blood concentration of haemoglobin and in the number of erythrocytes; due to the inability of the mature erythrocytes to survive in the circulating blood.

haematuria
the presence of blood in urine.

haemoglobinuria
the presence of haemoglobin in urine.

hepatic
pertaining to the liver.

lacrimation
the secretion of tears, especially in excess.

lassitude
a sense of weariness.

miosis
contraction of the pupil.

mutagen
an agent that raises the frequency of mutation above the spontaneous rate.

periorbital swelling
swelling about the eye socket.

peritoneal
pertaining to the serous membrane enveloping the abdominal viscera and lining the abdominal cavity.

pneumoconiosis
inflammation commonly leading to fibrosis of the lungs due to the irritation caused by the inhalation of dust. The degree of disability depends on the particles inhaled as well as on the level of exposure to them.

pruritus
localized or generalized itch due to irritation of sensory nerve endings.

pulmonary edema
an effusion of fluid into the alveoli and interstitial spaces of the lungs.

renal
pertaining to the kidney.

rhinitis
inflammation of the mucous membranes in the nose.

silicosis
a form of pneumoconiosis due to the inhalation of dust containing silica in the course of several years of occupational exposure. A slowly progressive fibrosis of the lungs is a predominant feature.

teratogen
an agent causing formation of a congenital anomaly or monstrosity.

tinnitus
a ringing, roaring, or hissing sound in one or both ears.

tumorigenic
causing or producing tumours.

Bibliography

American Conference on Governmental Industrial Hygenists Inc. *Documentation of the Threshold Limit Values*. Fourth Edition. Cincinnati: American Conference of Governmental Industrial Hygienists Inc., 1980.

Bennett G.W., J.M. Owens and R.M. Corrigan. *Trumans's Scientific Guide to Pest Control Operations*. Fourth edition. Duluth: Edgell Communications, 1988.

Brokerhof, A.W. *Control of Fungi and Insects in Objects and Collections of Cultural Value: "A State of the Art"*. Amsterdam: Centraal Laboratorium voor Onderzoek van Voorwerpen van Kunst en Wetenschap, 1989.

Burgess, H.D. and N.E. Binnie. "The Development of a Research Approach to the Scientific Study of Cellulosic and Ligneous Materials." *Journal of the American Institute for Conservation*. 29 (1990): 133-152.

Canadian Standards Association. *Installation and Ventilation of Ethylene Oxide Sterilizers in Health Care Facilities*. CAN/CSA-Z314.9-M89. Ottawa: Canadian Standards Association, 1989.

Clayton, G.D. and F.E. Clayton, eds. *Patty's Industrial Hygiene and Toxicology*. Third Edition. New York: John Wiley and Sons, 1981.

Dawson, John E. "The Effects of Insecticides on Museum Artifacts and Materials." In Zycherman, L.A. and J.R. Schrock, eds. *A Guide to Museum Pest Control*. Washington: Foundation of the American Institute for Conservation of Historic and Artistic Works and the Association of Systematics Collections, 1988.

Derrick, M.R., H.D. Burgess, M.T. Baker and N.E. Binnie. "Sulfuryl Fluoride (Vikane): A Review of its Use as a Fumigant." *Journal of the American Institute for Conservation*. 29 (1990): 77-90.

Ebeling, W. *Urban Entomology*. Berkeley: Division of Agricultural Sciences, University of California, 1978.

Edwards, S.R., B.M. Bell and M.E. King, eds. *Pest Control in Museums: A Status Report (1980)*. Kansas: Association of Systematics Collections, 1981.

Findlay, W.P.K. *Timber Pests and Diseases*. Oxford: Pergamon Press, 1967.

Hayes, W.J. *Pesticides Studied in Man*. Baltimore: Williams and Wilkins Co., 1982.

Hickin, N.E. *Household Insect Pests*. London: Associated Business Programmes London, 1974.

Hickin, N.E. *The Insect Factor in Wood Decay*. 3rd rev. ed., R. Edwards, ed. New York: St. Martins Press, 1975.

Hickin, N.E. *Termites: A World Problem*. London: Hutchinson and Co. Ltd., 1971.

Hickin, N.E. *The Woodworm Problem*. London: Hutchinson and Co. Ltd., 1972.

Monro, H.A.U. *Manual of Fumigation for Insect Control*. FAO Agricultural Studies, no. 56. Rome: Food and Agricultural Organization of the United Nations, 1969.

Munro, J.W. *Pests of Stored Products*. London: Hutchinson and Co. Ltd., 1966.

Sax, N.I. *Dangerous Properties of Industrial Materials*. 2 vols. New York: Van Nostrand Reinhold Co., 1984.

Sax, N.I. *Dangerous Properties of Industrial Materials Report*. Vol. 1 to current issue. New York: Van Nostrand Reinhold, 1980.

Scott, E.W., W.S. Abbott and J.E. Dudley, Jr. *Results of Experiments with Miscellaneous Substances against Bedbugs, Cockroaches, Clothes Moths, and Carpet Beetles*. USDA Bulletin, No. 707. Washington, DC: U.S. Department of Agriculture, 1918.

Sittig, M. *Handbook of Toxic and Hazardous Chemicals*. Park Ridge: Noyes Publications, 1981.

Soderman, J.V., ed. *Handbook of Identified Carcinogens and Noncarcinogens: Carcinogenicity-Mutagenicity Database*. Boca Raton: CRC Press, 1981.

Strang, Thomas J.K. and John E. Dawson. *Controlling Museum Fungal Problems*. Technical Bulletin No. 12. Ottawa: Canadian Conservation Institute, 1991.

Strang, Thomas J.K. and John E. Dawson. *Controlling Vertebrate Pests in Museums*. Technical Bulletin No. 13. Ottawa: Canadian Conservation Institute, 1991.

Tatken, R.L. and R.J. Lewis, Sr., eds. *Registry of Toxic Effects of Chemical Substances*. 1981-1982 edition. Cincinnati: U.S. Department of Health and Human Services, 1983.

Ward, P.R. *Getting the Bugs Out*. Victoria, B.C.: Friends of the Provincial Museum, 1976.

Ware, G.W. *The Pesticide Book*. San Francisco: W.H. Freeman and Co., 1978.

Wellheiser, J.G. *Nonchemical Treatment Processes for Disinfestation of Insects and Fungi in Library Collections*. IFLA Publications 60. Munich: KG Saur, 1992.

Worthing, C.R. and S.B. Walker, eds. *The Pesticide Manual: A World Compendium*. Eighth edition. Lavenham: British Crop Protection Council and Lavenharn Press, 1987.

Zycherman, L.A. and J.R. Schrock, eds. *A Guide to Museum Pest Control*. Washington: Foundation of the American Institute for Conservation of Historic and Artistic Works and the Association of Systematics Collections, 1988.